Fermi National Accelerator Laboratory

ELECTROWEAK RADIATIVE CORRECTIONS TO W AND Z BOSON PRODUCTION IN HADRONIC COLLISIONS[a]

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ABSTRACT

Some results of a calculation of electroweak radiative corrections to W and Z boson production in hadronic collisions are presented.

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Some results of a calculation of electroweak radiative corrections to W and Z boson production in hadronic collisions are presented.

Over the last five years, the Standard Model of electroweak interactions has been successfully tested at the one loop level. Experiments at LEP and the SLC have determined the properties of the Z boson with a precision of 0.1% or better, and the range of the top quark mass has been correctly predicted by comparison with loop corrections. Currently, the Z boson mass is known to ± 2.2 MeV, whereas the uncertainty of the W boson mass, M_W, is ± 125 MeV. A precise measurement of M_W and the top quark mass would make it possible to derive indirect constraints on the Higgs boson mass via top quark and Higgs boson electroweak radiative corrections to M_W.

A significant reduction of the W boson mass uncertainty is expected from measurements at LEP2 and the upgraded Tevatron. The ultimate precision expected for M_W from the LEP2 experiments combined is approximately 40 MeV. At the Tevatron, integrated luminosities of $\mathcal{O}(1 \text{ fb}^{-1})$ are envisioned in the Main Injector Era, resulting in an uncertainty of approximately 50 MeV per experiment. Further upgrade of the Tevatron might be possible with a goal of an overall integrated luminosity of $\mathcal{O}(30 \text{ fb}^{-1})$ and a precision on M_W of about 15 MeV [1].

The determination of the W boson mass in a hadron collider environment requires a simultaneous precision measurement of M_Z. When compared to the value measured at LEP, the Z boson mass helps to accurately determine the energy scale and the resolution of the charged lepton energy.

In order to measure M_W and M_Z with high precision, it is crucial to fully control higher order QCD and electroweak (EW) corrections. In this short contribution, we concentrate on the latter. So far, only the final state photonic corrections have been calculated [3], using an approximation which indirectly
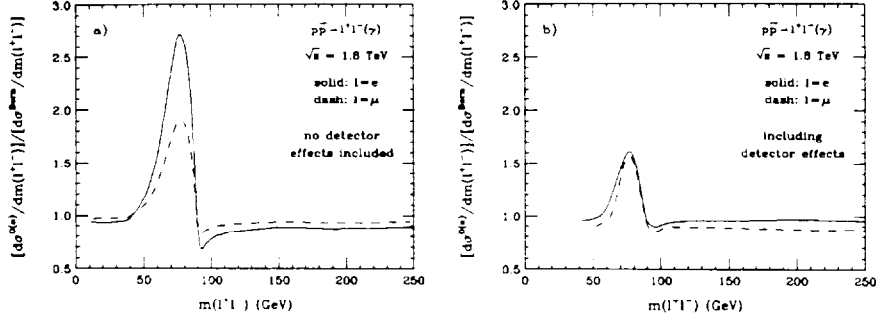
Figure 1: Ratio of NLO to LO differential cross sections for Z boson production as a function of the di-lepton invariant mass at the Tevatron.

estimates the virtual part from the inclusive $\mathcal{O}(\alpha^2)$ $W \to \ell\nu(\gamma)$ and $Z \to \ell^+\ell^-(\gamma)$ width and the hard photon bremsstrahlung contribution. Here we summarize the results of a calculation which includes both initial and (exact) final state EW corrections, as well as initial – final state interference terms.

Our calculation is performed using standard Monte Carlo phase space slicing techniques for NLO calculations. The resulting $p\overset{(-)}{p} \to \gamma^*, Z \to \ell^+\ell^-(\gamma)$ and $p\overset{(-)}{p} \to W \to \ell\nu(\gamma)$ cross sections are independent of the soft and collinear cutoff parameters used to divide the phase space into $2 \to 2$ and $2 \to 3$ regions. Special care has to be taken in calculating the initial state radiative corrections: mass (collinear) singularities have to be absorbed into the parton distribution functions (PDF) through factorization, in complete analogy to the QCD case. However, EW corrections to the PDF evolution are not included in our calculation; they are expected to be small[4]. For Z boson production, purely weak corrections are very small and therefore are not included. In the W case, weak corrections were included in the calculation as required by gauge invariance, and the corrections were consistently separated into gauge invariant initial and final state contributions[5]. The technical details of our calculations will be presented in Refs. 6 and 7.

As expected, we find that the final state corrections completely dominate over the entire mass range of interest. Both the initial state and the interference contributions are small and therefore have a negligible impact on the extracted W/Z boson mass. In Fig. 1, we show the ratio of NLO to LO differential cross sections for Z boson production as a function of the di-lepton invariant mass, $m(\ell^+\ell^-)$. When no detector effects are included (Fig. 1a), the corrections are large due to the occurrence of mass singular logarithms

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$\log(M_Z^2/m_\ell^2)$ (m_ℓ denotes the lepton mass) in the collinear region. These logarithms also explain the large difference in the differential cross section between electrons and muons. The collinear behavior of the final state corrections also significantly influences the shape of the $m(\ell^+\ell^-)$ distribution, as a large fraction of the events shifts from the peak region to lower values of $m(\ell^+\ell^-)$. In Fig. 1b, the same ratio is plotted as in Fig. 1a, now taking into account CDF detector resolution effects. While the mass singular logarithms are removed by the detector effects in the electron case, residual effects of the $\log(M_Z^2/m_\ell^2)$ terms remain in the muon case due to differences in the experimental criteria used to identify electrons and muons[7].

EW corrections have a smaller effect on the W transverse mass distribution than on the Z invariant mass distribution; including detector effects, they reduce the cross section by a few per cent in the peak region. The shifts in the W/Z boson mass extracted from the transverse/invariant mass distribution that we obtained are consistent with the values obtained by the CDF and D∅ collaborations. A preliminary comparison of the approximation used so far[3] with our complete calculation reveals that the difference corresponds to a shift in the mass of the order of 10 MeV.

In summary, we have presented selected results of a calculation of weak boson production in hadronic collisions which includes initial and final state EW corrections, as well as initial-final state interference terms. Final state corrections dominate, while initial state corrections are small after factorizing the collinear singularities into the parton distribution functions. Our calculation substantially improves the treatment of EW corrections to W/Z production at hadron colliders, and will allow to considerably reduce the systematic uncertainties associated with the EW corrections when the W and Z boson masses are extracted from Tevatron data.

References

1. see the TEV33 Committee Report Executive Summary, http://www-theory.fnal.gov/tev33.ps.
2. F. Abe *et al.* (CDF Collaboration), *Phys. Rev.* D **52**, 4784 (1995). S. Abachi *et al.* (D∅ Collaboration), Fermilab-Pub/96-177-E.
3. F. Berends and R.K. Kleiss, *Z. Phys.* C **27**, 365 (1985).
4. J. Kripfganz and H. Perlt, *Z. Phys.* C **41**, 319 (1988). H. Spiesberger, *Phys. Rev.* D **52**, 4936 (1995).
5. D. Wackeroth and W. Hollik, Fermilab-Pub-96/-094-T (June 1996).
6. U. Baur, S. Keller and D. Wackeroth, in preparation.
7. U. Baur, S. Keller and W. Sakumoto, in preparation.